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THE PRESENT STATUS OF THE ALFALFA WEEVIL IN CALIFORNIA

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CONTENTS

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A. E. MICHELBACHER[2]

TEN YEARS have passed since the alfalfa weevil, *Hypera postica* Gyll., was found in lowland middle California on May 13, 1932, although it was first reported in the state from Sierra County in 1923. Since that time it has been closely studied, and an attempt is made in this paper to summarize the more important observations made during that interval. The period has been sufficiently long so that some idea as to the future status of the alfalfa weevil as a pest can be determined. It is fortunate that to date the weevil has not become the serious pest that many predicted. Although it occurs elsewhere in the state, only the infestation which is found in lowland middle California is discussed in detail here; it is in this region that the weevil has access to an important alfalfa-producing area. Some aspects of the alfalfa-weevil problem have already been treated by the author and his associates; these are referred to later in the text.

LIFE HISTORY

The adult alfalfa weevils are small snout beetles (fig. 1, *G* and *H*) about ¼ inch in length. When freshly emerged they are light brown in color but in a short time become a golden brown, with darker markings on the dorsum. The bodies are covered with minute scales and hairs. As the weevil grows older there is a tendency for the hairs and scales to wear off and the beetles become darker. Old individuals may become so rubbed that they appear polished and nearly black.

The eggs are small, oval, and yellow or orange yellow. They are laid in the stems (fig. 1, *A*) of host plants in batches of a few to about 25. The females insert their ovipositors in the stem through a hole that they make with their beaks. After the eggs are laid, the females usually plug up the entrance in the stems with a secretion. As the incubation period progresses the eggs become dingy.

The legless larvae on hatching eat their way out of the stems and work their way to the growing tips, where they feed in the developing leaf buds. The young larvae are light yellowish green or tan in color, with black heads. In growing to maturity they cast their skins three times. The larger larvae (fig. 1, *B* and *C*) feed on the older leaves and when full-grown are about ¼ inch long and green in color. There is a rather wide dorsal, white stripe running down the back; and on either side

[1] Received for publication July 29, 1942.

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there is a faint white line. The body is marked with many wrinkles, which extend over the back and sides. On reaching maturity the larvae crawl to the ground and spin delicate, netlike silken cocoons (fig. 1, *D*). The cocoons are roughly globular and are often partly enveloped by one or

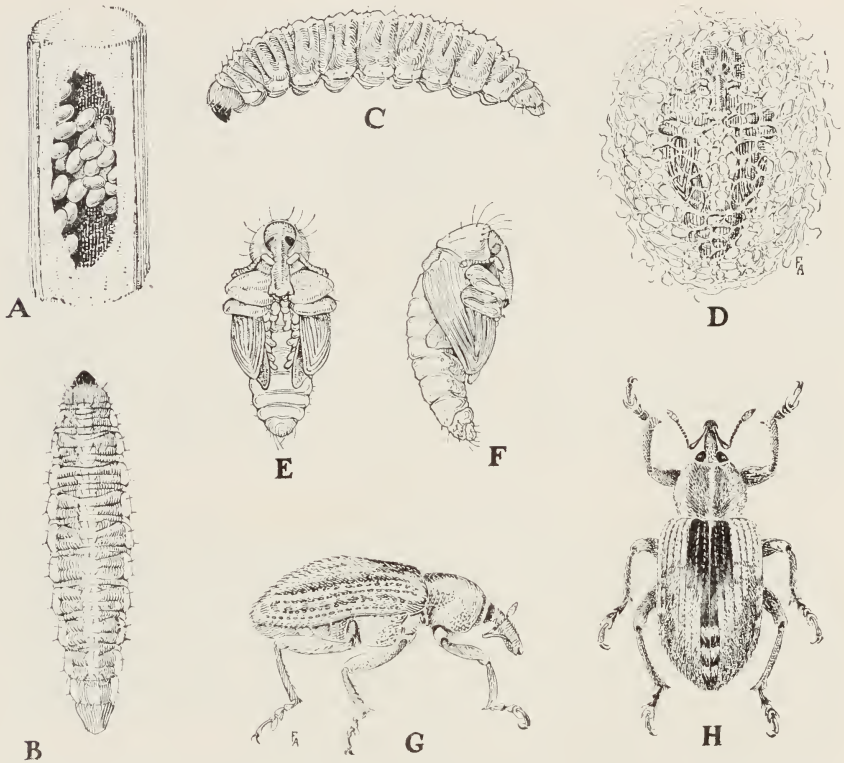

Fig. 1.—Life cycle of alfalfa weevil, *Hypera postica* Gyll.: *A*, alfalfa stem cut open showing a cluster of eggs; *B*, dorsal view of last-instar larva; *C*, lateral view of last-instar larva; *D*, pupa within lacelike cocoon; *E*, pupa removed from cocoon, ventral view; *F*, lateral view of pupa; *G*, lateral view of adult; *H*, dorsal view of adult. (All × 6.) (From *Hilgardia* vol. 13, no. 3.)

more dead leaves. They are lightly attached to the rubbish on the ground or to the stubble at the base of the plants. After the cocoon is complete the larvae spend a day or two in a prepupal condition before they pupate. The pupae (fig. 1, *E* and *F*) are at first pale yellowish green, but change to a light brown as maturity is reached. After transformation, the adult beetles remain within the cocoon a few days before cutting their way out.

NUMBER OF GENERATIONS

Because of the moderate climate in lowland middle California, the alfalfa weevil passes through more than one generation in a year. This

is in marked contrast to what occurs in the more continental climates such as that found in the Great Basin area of the United States. Here there is but a single full generation, and a bare beginning of a second. Webster (1912),[3] Parks (1913, 1914), Reeves and associates (1916), and Snow (1928) have shown that some of the beetles of the first generation are ready to lay eggs by October. This, of course, is too late in the season for the progeny to complete their development. Yakhontov (1934) reported that after the female beetles emerge there is a diapause, and where the temperature does not fall below 12° C nor rise above 25°, about 55 to 60 days must elapse before sexual maturity is reached. Snow (1928) found that in the Great Basin a period of at least 4 months was necessary for the weevils to reach sexual maturity. The discrepancy in the length of time necessary to break the diapause, as reported by these two workers, can probably be accounted for by the conditions under which their respective investigations were conducted. In the Great Basin most of the beetles emerge during the months of June and July. This is during the hottest part of the year; and, since Snow studied developments under field conditions, it would be expected that the high temperatures would tend to prolong the diapause. Observations in middle California tend to substantiate the findings of Yakhontov. Here the first-generation adults make their appearance during April. At this time, and for the next month or two, temperatures are favorable for the development of the sexual products; under this influence new-generation adults reach sexual maturity, and during the latter part of June and July, a second generation makes its appearance. This was shown to be the case by Michelbacher and Essig (1935). The second generation does not appear to be so large as the first, probably because it comes at the warmest time of the year. The frequent cutting of the alfalfa during this period prevents a mass build-up in the population.

In the cooler, more moderate coastal regions there is evidence that there are even more than two generations. In the early years of the investigations, before the larval parasite *Bathyplectes curculionis* (Thomson) exerted such a marked control over the pest in the agricultural region adjacent to the San Francisco Bay area, there were three definite larval peaks. These peaks can best be accounted for by assuming that in this region there are three, or at least two and a partial third, generations. Certainly in this climatic zone, summer temperatures do not become hot enough to greatly prolong the diapause. However, in the more continental climate of the San Joaquin Valley the summer temperatures are considerably higher, and only two definite broods of weevils make their appearance.

[3] See "Literature Cited" for complete data on citations mentioned in the text by author and date of publication.

Fig. 2.—The clover leaf weevil, *Hypera punctata* (Fabr.), a common insect in alfalfa fields, often confused with the alfalfa weevil. (From *Insects of Western North America*, Macmillan Co. Reproduced by permission of the copyright owners.)

Fig. 3.—Mature larvae of the alfalfa weevil, left, and the clover leaf weevil, right. The latter are much larger and have pink lines bordering the white dorsal stripe. Immature forms of the clover leaf weevil also have the posterior part of the body pinkish. (From Bul. 567.)

OTHER CLOSELY RELATED WEEVILS IN CALIFORNIA

There are two other species of weevil that are closely related to the alfalfa weevil. The larvae of both of these feed upon the foliage; and, like the alfalfa weevil, they have been introduced into California. The clover leaf weevil, *Hypera punctata* (Fabr.), shown in figure 2, is much larger than the alfalfa weevil. The adult is several times as large, is more robust, and has a shorter snout. Besides being larger, the larvae (fig. 3) have pink lines bordering the white dorsal stripe, and the posterior portion of the body of smaller larvae is pinkish. The clover leaf weevil

is more widespread in California than is the alfalfa weevil, but has never become a pest.

The second species, *Hypera brunneipennis* (Boh.), illustrated in figure 4, *C* and *D*, is very closely related to the alfalfa weevil (fig. 4, *A* and *B*), from which it is not easily distinguished. It was not discovered in this country until the spring of 1939. This is a species adapted to life in a hot climate and so far is known to occur only in the Yuma Valley of Arizona and the adjacent part of California.

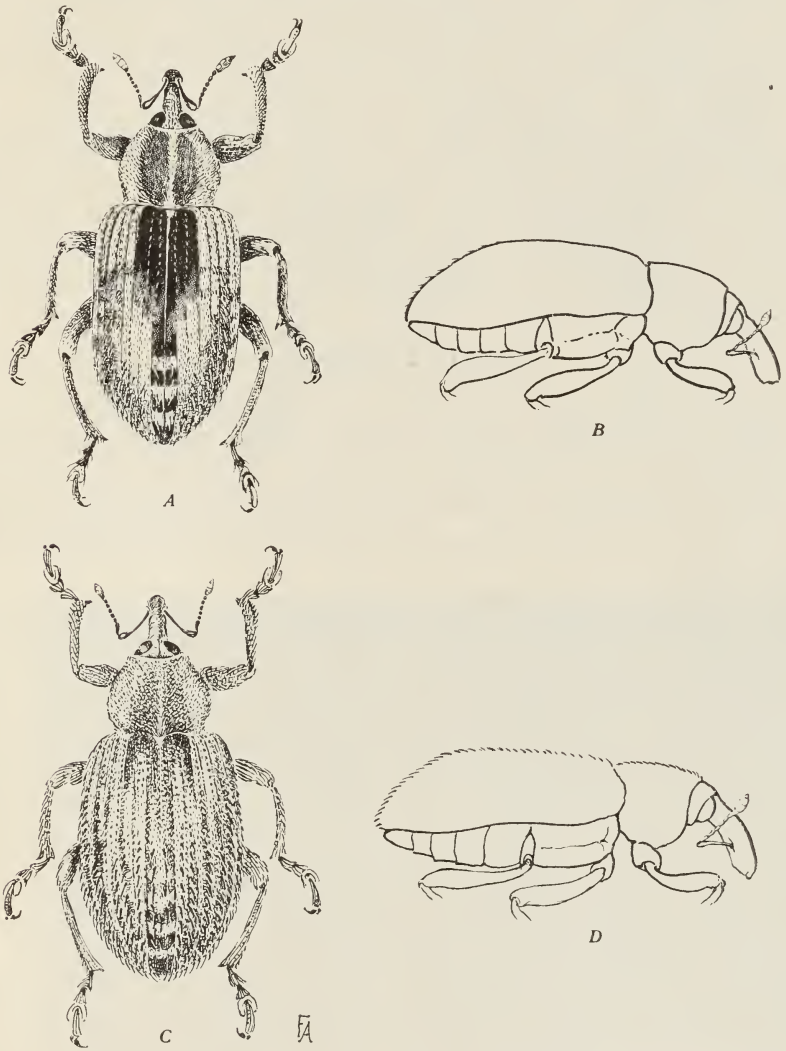

Fig. 4.—*A*, Dorsal view, and *B*, lateral view, of the adult alfalfa weevil, *Hypera postica* Gyll.; *C*, dorsal view, and *D*, lateral view, of adult *H. brunneipennis* (Boh.). (From *Hilgardia* vol. 13, no. 3.)

HOST RANGE

In California the alfalfa weevil has been found breeding on the following host plants: alfalfa, *Medicago sativa;* toothed bur clover, *Medicago hispida;* black medic, *Medicago lupulina;* annual yellow sweetclover, *Melilotus indica;* and white sweetclover, *Melilotus alba.* All these plants are satisfactory hosts and are probably preferred in the order given. The first four have been found heavily infested.

In cage tests the alfalfa weevil completed its life cycle on the following plants: *Melilotus hubamensis, Vicia dasycarpa,* and hairy vetch, *Vicia villosa.* These plants beyond a doubt would serve as hosts in the field. There are many other plants also on which the adult weevil readily feeds, and some of these would undoubtedly serve as hosts and aid the weevil in spreading to new areas.

DESTRUCTIVENESS

The chief damage to alfalfa is done by the larvae feeding on the developing buds and on the leaves (fig. 5). When heavily attacked the plants may be nearly defoliated (fig. 6). The adults feed on the leaves and stems of the alfalfa. They make deep feeding punctures, often eating the epidermis from the stems and injuring the leaves by making longitudinal slits.

The weevil has been most destructive in regions having climate similar to that found in the Great Basin. In such locations damage is likely to be most serious when weather conditions are such that the adults in early spring lay most of their eggs in a relatively short period. Where this occurs there is a mass attack of the larvae on the alfalfa, which results in defoliation and destruction of the first crop. Heavily infested fields turn grayish in color. Not only is the first crop ruined, but the second may be greatly delayed in starting because of the feeding of the weevil larvae and newly emerged adults on the developing buds. The damage done by the alfalfa weevil in the Great Basin varies with locality and with weather conditions from year to year. It has held the interest of numerous entomologists in that region; and among the important publications that treat it as a destructive pest are those of Titus (1909, 1910, 1913), Webster (1912), Parks (1913), Reeves (1917, 1927), Reeves and associates (1916, 1920), Hagan (1918), Wakeland (1920, 1921, 1924, 1925), Snow (1925), and Newton (1926, 1933). In Central Asia the weevil attacks alfalfa in mass and causes serious losses; it is discussed by Yakhontov (1934). In Europe, it has been reported by various investigators as a pest from several countries, as follows: by Lind and his co-workers (1917), in Denmark; Martelli (1911), in Italy; Marchal and Foex (1921) and Molz and Muller (1929), in France;

Fig. 5.—Alfalfa plants showing the injury done by the larvae of the alfalfa weevil. Such injury is seldom noted by the grower unless his attention has been called to it. (From Bul. 567.)

Fig. 6.—Alfalfa plants seriously damaged by the larvae of the alfalfa weevil. Such injury is caused by large populations of weevils and may result in considerable losses. Under these conditions the injured tops become dry and whitish, and artificial control is justifiable. (From Bul. 567.)

Chorbadzhiev (1931) in Bulgaria; Vassilier (1913) in Russia; and Kaufmann (1939), as a serious pest in Germany. Kaufmann stated that although it causes considerable damage, mass attacks as reported from the Great Basin area of the United States are practically unknown in Germany.

In middle California the alfalfa weevil has not proved to be a serious pest. Only in localized areas has it caused severe damage. Over most of the infested region it exists in almost unnoticed numbers. During late years it has not been a pest in the more coastal regions; what little damage has occurred has been confined to the infested portion of the San Joaquin Valley. Here a few fields have been severely attacked and damage has resulted in the complete destruction of the first crop. In some cases there has been some delay in the growth of the second crop. In a heavily infested area over 4,000 larvae may be collected per 100 sweeps of a sweeping net; but in fields a mile or two away the number may be less than 50. The amount of damage done has varied from year to year and was most serious in 1940. Since then there has been a marked falling off in the number of weevils. The population encountered in 1942 was very small, and not a single field suffered any economic injury.

CLIMATIC CONDITIONS UNDER WHICH THE WEEVIL EXISTS IN LOWLAND MIDDLE CALIFORNIA

In the part of California under discussion the alfalfa weevil occurs in the type of climate referred to by Michelbacher and Leighly (1940) as having a short winter interruption but no summer interruption. In such a climate there is a short period in the winter when temperatures are too low for adult activity. In the area just mentioned the type of climate can be further subdivided. In the first subdivision falls the more moderate climate found adjacent to San Francisco Bay. The climate of this region tends to blend into the type where there is no winter interruption in the activity of the adult weevil. In the second division falls the climate of the northwest portion of the San Joaquin Valley. Here the climate is more continental, with slightly longer winter interruption. Toward the southern boundary of the weevil-infested area it blends into the climatic type having both a winter and a summer interruption; so the adult weevils become inactive in the winter from low temperatures and in the summer from high temperatures.

The reaction of the weevil and its larval parasite, *Bathyplectes curculionis,* to these two climates is different. The more moderate climate of the coastal region is apparently favorable to the alfalfa weevil but relatively even more suited to *Bathyplectes:* the result has been a marked reduction in the alfalfa-weevil population since the parasite was introduced into the region. The climate of the weevil-infested region

in the San Joaquin Valley does not seem to be so well suited for the weevils' activity as is the climate found in the coastal areas, but it is also relatively less favorable for *Bathyplectes*. As a result, much higher weevil populations can be expected in the San Joaquin Valley than in the more moderate climates. In the early years of the investigation, maximum populations were found in the more moderate climates, while during the later years the largest populations have occurred in the San Joaquin Valley. In order to demonstrate the changes that have occurred, table 1 has been prepared. The largest number of larvae and adults

TABLE 1

Trend of the Maximum Populations of the Alfalfa Weevil, 1933 to 1941

Year	Number of weevils per 100 sweeps of an insect net in the most heavily infested field					
	San Francisco Bay region		Pleasanton region		Northwest part of San Joaquin Valley	
	Larvae	Adults	Larvae	Adults	Larvae	Adults
1933	1,762	128	6,482	205	642	93
1934	2,020	103	4,187	80	1,194	51
1935	1,444	77	727	103	1,672	47
1936	1,573	65	832	27	5,893	108
1937	434	4	332	8	2,072	151
1938	624	7	139	37	3,300	319
1939	158	10	90	4	6,038	141
1940	367	14	30	0	4,681	376
1941	112	5	0	0	2,734	191

collected per 100 sweeps for each year from 1933 to 1941 inclusive in the San Joaquin Valley and the region adjacent to San Francisco Bay is shown. The results obtained in the agricultural region about Pleasanton are also included. The climate of this region is somewhat intermediate, although more like that of the San Francisco Bay area than that of the San Joaquin Valley.

WEATHER CONDITIONS AND THE ALFALFA WEEVIL

The adult alfalfa weevil is very much influenced by weather conditions. It is apparently most active at temperatures of about 70° to 75° F. In the autumn, winter, and spring, on still days, the weevils may crawl up the plants in large numbers; and on rare occasions individuals have been observed to fly. In observing population trends in alfalfa fields, the largest number of adults are collected by sweeping when weather conditions are favorable, and the number collected per 100 sweeps can be rather accurately utilized in predicting the size of the larval population. If conditions are not favorable for adult activity on the plants, few can be collected, and little can be determined as to the possible size of the larval population. For this reason surveys during

the winter were usually conducted, if possible, on days that were favorable for adult activity.

Some evidence was obtained which indicated that frosty mornings followed by warm daytime temperatures caused the death of numerous larvae. After a series of such days many dead larvae were found in alfalfa fields in the area adjacent to San Francisco Bay. When these larvae were examined, it appeared that they had been killed by some physical condition rather than by a fungus as might have been suspected.

The weather conditions at the time the first crop of alfalfa is cut are very important. Sometimes there is a period of rainy weather which may make it impossible to cut the hay at the right time. Cutting may be delayed for as long as 2 weeks, and if a field is heavily infested considerable damage may occur. In 1940 such conditions were encountered in the San Joaquin Valley, accompanied by a mild winter and spring. There was a rapid build-up of the pest, and in the more heavily infested fields the larval population ranged from 2,000 to more than 4,000 per 100 sweeps for as long as a month before the alfalfa was cut. The alfalfa was unable to withstand this prolonged, heavy attack, and in several cases the hay was rendered worthless. If cutting could have taken place at the normal time, much of the hay would have been saved, for the most serious damage occurred during the 2 weeks when cutting had to be delayed because of the wet weather. Delaying cutting also allowed a maximum period for the weevils to complete their development and emerge as adults, before cutting and cultural kill could come into play.

If, at cutting time, the weather is clear and warm, large numbers of the immature stages of the weevil are killed. All the wholly exposed pupae and many that are protected by the crowns of the alfalfa succumb to the heat.

Wet weather may also adversely affect the alfalfa weevil. Conditions are made favorable for attacks by fungus diseases. Rockwood (1916) has reported the entomogenous fungus *Sporotrichum globuliferum* Speg. attacking the alfalfa weevil in Utah during the spring. In California it has been observed that in winter and spring the larvae of the clover leaf weevil are very heavily attacked by a fungus. Whether or not this disease attacks the larvae of the alfalfa weevil is not known, although there is good evidence that the pupae are killed by fungi. Whatever may be the cause, a large portion of the alfalfa-weevil population was killed during the wet winter and spring of 1941. On May 6, in a heavily infested field near Tracy, a search was made for *Bathyplectes* cocoons. Few were found, and nearly all the alfalfa-weevil cocoons collected from which the beetles had not emerged contained dead pupae or larvae. Apparently death had not been due to a fungus, but was the direct result of the very wet condition. Throughout the heavily

infested region this same thing must have occurred; there was a marked falling off of the weevil population. The decrease has been so great that there seems little likelihood of a single field's suffering a serious attack during the 1942 season. The reduction in the alfalfa-weevil population in the San Joaquin Valley for 1941 below that of 1939 and 1940 can be ascertained by comparing larval and adult population trends as shown in figures 7 to 9.

SPREAD OF THE ALFALFA WEEVIL IN CALIFORNIA

The original infestation of the alfalfa weevil was in Sierra County, in 1923. By 1925 it had invaded Plumas and Lassen counties, and by 1929 Alpine County. The entire infested region was east of the Sierra Nevada; but in 1932 the pest was found in five central counties: Stanislaus, San Joaquin, Alameda, Santa Clara, and Contra Costa. It was now in the heart of a large alfalfa-producing section.

Despite the fact that the pest had invaded a region where alfalfa fields are contiguous, its spread has been slow; in this area only Merced County has been added to the five infested counties mentioned above. Here the weevil was found near Gustine in 1933. Since 1932, infestations have also been found in Siskiyou and Modoc counties. On the map in figure 10, the known infestation of the alfalfa weevil up to and including 1932 is shown in black, while the spread of the weevil since then is shaded. Aside from the infestation in lowland middle California, the weevil occurs in regions of this state having climates similar to those found in the Great Basin. It has not been practicable to study the pest in those areas, but it is safe to conclude that the weevils' behavior there is similar to that in the Great Basin. California farmers are more concerned with what has occurred in middle California. An examination of figure 10 shows that there has been very little spread of the weevil to the south. Eastward there has been a greater spread, but in no case have serious infestations been found; and the greatest total spread from the known infestation in 1932 has been only about 25 miles. The southern limit of the infestation cuts across one of the most important areas of alfalfa production in the state; and, because the weevil has failed to spread rapidly to the south, it is believed that a climatic barrier is being reached. The climatic limitations of the pest have been thoroughly discussed by Michelbacher and Leighly (1940).

Within most of the infested area there is considerable local movement of the weevil, which is shown by the fact that it becomes established in newly planted fields during the first year. Weevils have been collected in such fields even though the nearest established alfalfa field may be a mile away. This would indicate that where climatic conditions are favorable a rapid dissemination of the weevil could be expected.

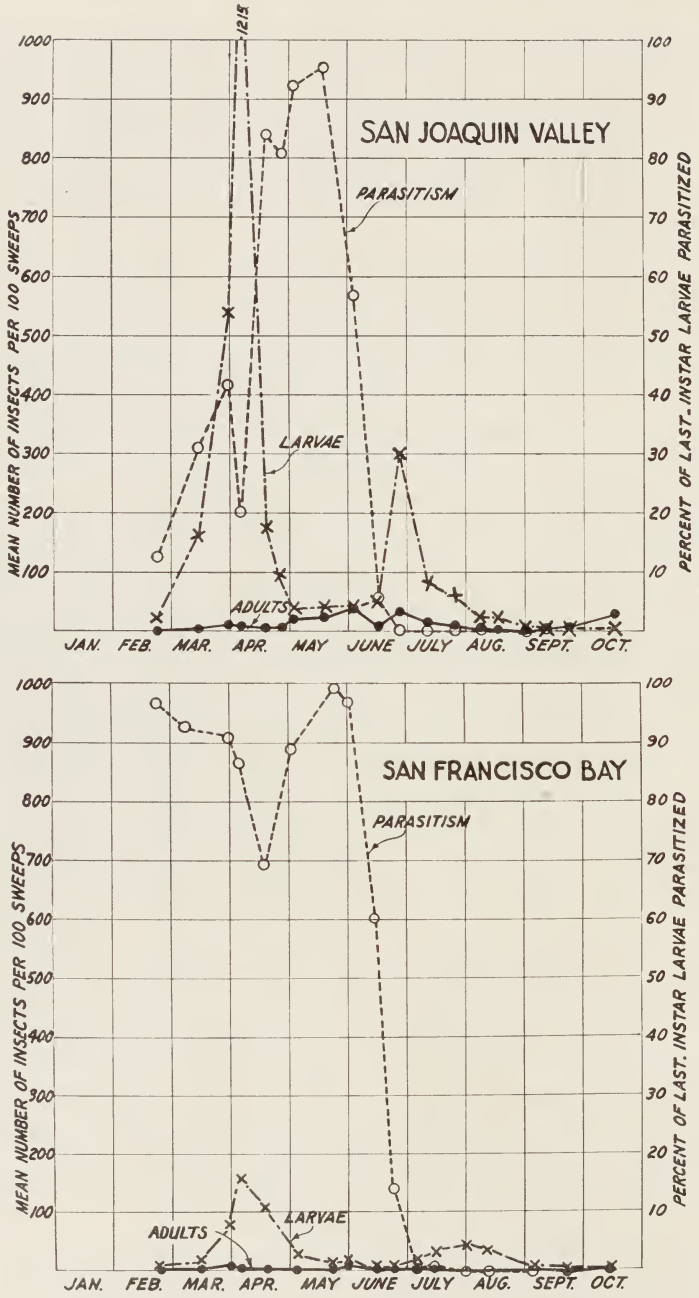

Fig. 7.—Alfalfa-weevil population and parasitism in the northwest portion of the San Joaquin Valley and in the agricultural region adjacent to San Francisco Bay, 1939; average number of larvae and adults collected per 100 sweeps of an insect net and percentage of last-instar weevil larvae parasitized by *Bathyplectes curculionis*.

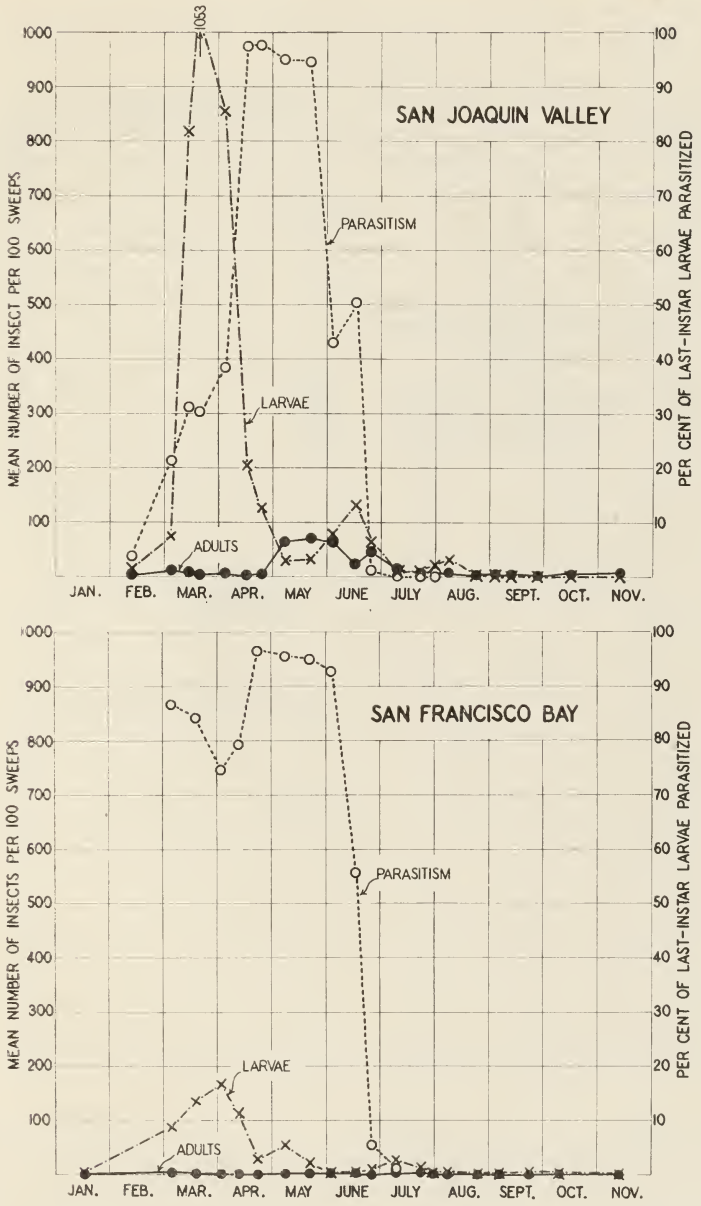

Fig. 8.—Alfalfa-weevil population and parasitism in the infested portion of lowland middle California, 1940: average number of larvae and adults collected per 100 sweeps of an insect net, and percentage of last-instar weevil larvae parasitized by *Bathyplectes curculionis*.

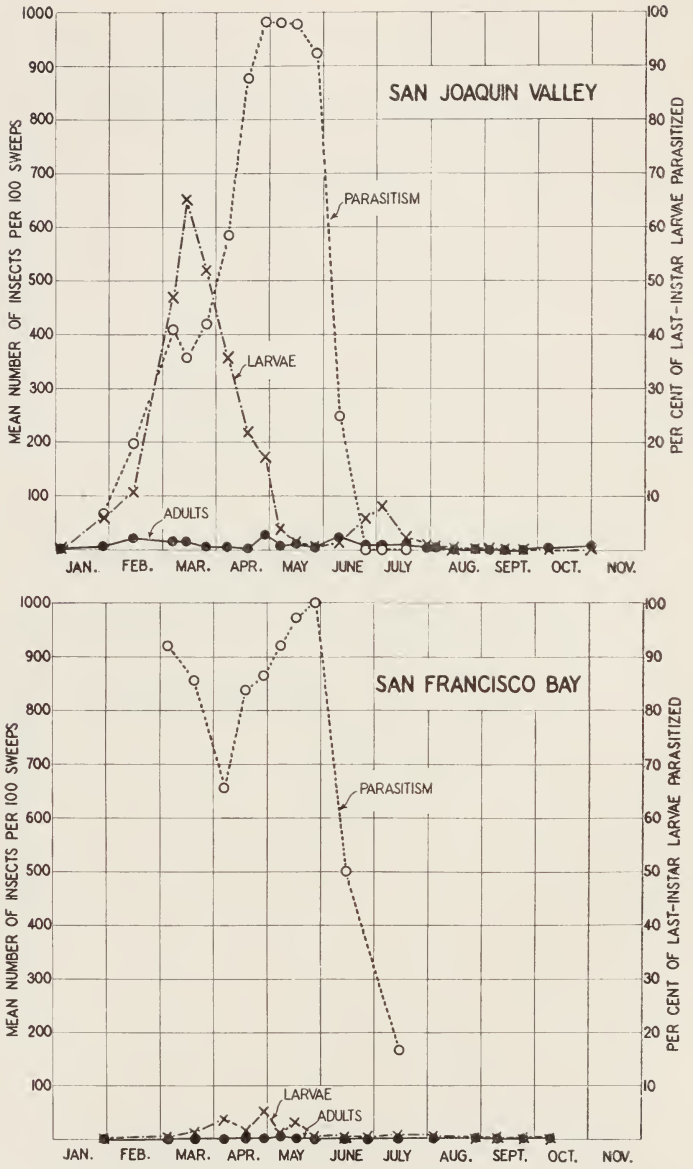

Fig. 9.—Alfalfa-weevil population and parasitism in the infested portion of lowland middle California, 1941: average number of larvae and adults collected per 100 sweeps of an insect net, and percentage of last-instar weevil larvae parasitized by *Bathyplectes curculionis*.

CULTURAL CONTROL

The maintenance of good, vigorous stands of alfalfa is one of the best means of avoiding serious attacks by the alfalfa weevil. Timely cutting is also of value in holding the weevil population in check. The first crop should be cut as soon as it is ready—if possible before the first-generation

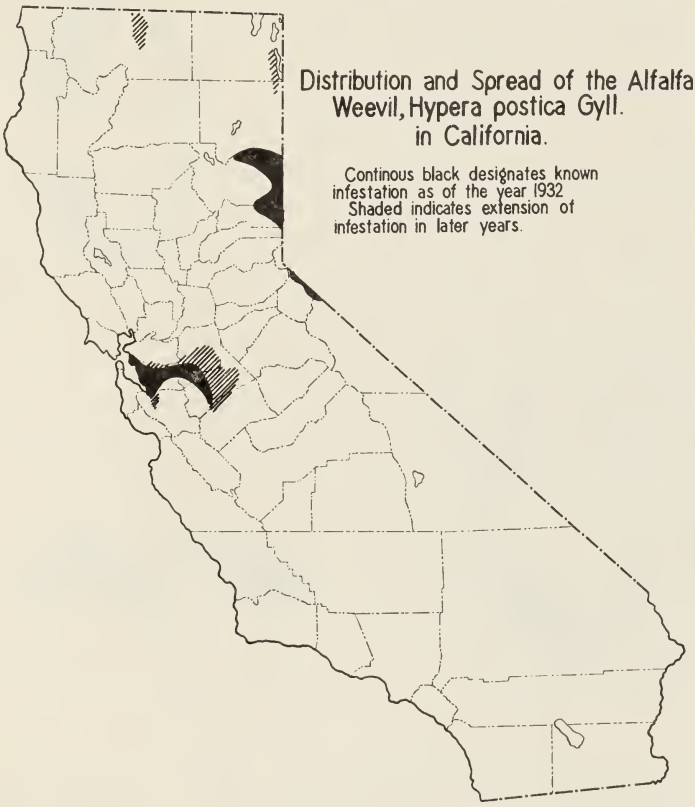

Fig. 10.—Areas in California infested by the alfalfa weevil in 1932, and the spread of the insect since that year.

larvae have had opportunity to complete their development and emerge as adults. The immature stages are much less resistant to conditions following cutting of the alfalfa than are the adults.

The fields should go into the winter with the stubble cut as short as possible. This eliminates much growth that would otherwise afford protection for the pest. If the late autumn and winter are dry, the fields can be "sheeped off," provided there is no danger of noxious weed seeds' being carried in the wool. Winter cultivation is also a desirable practice where the stands are not so thick that they would be injured by the tools, or where the danger of spreading disease is not too great.

In a heavily infested area new fields should be planted with care. There is considerable evidence that beetles may move in large numbers from heavily infested old fields to new ones. This has occurred where a new field has been planted adjacent to an older one. Such a combination is favorable to the alfalfa weevil. A newly planted field grows much

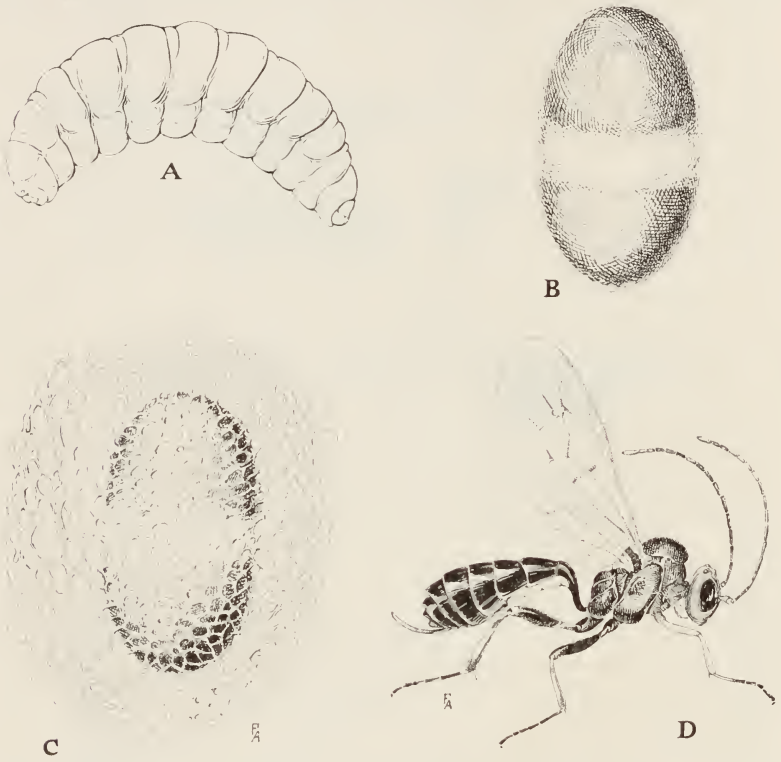

Fig. 11.—Life cycle of *Bathyplectes curculionis*: *A*, mature larva at time of leaving body of host; *B*, cocoon removed from within host cocoon; *C*, cocoon in normal position within cocoon of host; *D*, adult female parasite. (All × 12.) (From *Hilgardia* vol. 13, no. 3.)

more slowly during the beginning of the season than do older fields. As a result, the older fields are cut for the third time while newly planted ones are still growing their second crop. The third crop in older fields is usually cut during the last part of June or the first of July. Frequently at this time there is a period of hot weather. On such occasions the adult weevils are probably stimulated to seek a cooler environment than that which occurs in the dry stubble fields; and so they migrate, in part at least, to newly planted fields. There is no doubt that this occurs, for the weevil population trend was carefully followed in several young fields. At the start of the season these fields were nearly

free of weevils. Although there were practically no larvae, suddenly, about the first of July, adults were found to be rather abundant. These must have migrated to the new fields; and the migrations must at times be large, for there is at least one case where the first crop of hay was severely injured the second year after alfalfa was planted. Alfalfa in continuously growing condition, adjacent to heavy infestations, tends to perpetuate the population at a dangerous level. If possible, an old, heavily infested alfalfa field should be plowed out before a new field is planted next to it.

BIOLOGICAL CONTROL

The larval parasite *Bathyplectes curculionis* (fig. 11) was introduced into the weevil-infested region of lowland middle California by the United States Department of Agriculture, Bureau of Entomology and Plant Quarantine, during 1933 and 1934. The parasite readily became established and in the more moderate climates has been very important in reducing the alfalfa-weevil population. Parasitism trends have been studied since 1935, and it was found that climate greatly influences the length of time that the parasite remains active. Cool temperatures extend the period, and for this reason the parasite has been most effective in the coastal regions. The results of the investigation up to 1938 have been published (Michelbacher, 1940*a*). The work in 1939 (Michelbacher, 1940*b*) substantiated the previous findings and further showed that parasitism is so complete that extensions of the weevil infestation in the moderate climates might be very difficult to detect. The effectiveness of *Bathyplectes* can hardly be overestimated. In 1933, at Pleasanton, as many as 6,000 weevil larvae could be collected per 100 sweeps of an insect net, while in 1940 the pest was so scarce that not enough could be collected to continue parasitism studies (fig. 12).

Two surveys were made in 1941 without finding a single weevil. In the region adjacent to San Francisco Bay the population has also been much reduced, and it was with difficulty that enough larvae were collected in 1941 for parasitism studies. In the San Joaquin Valley, *Bathyplectes* is not nearly so effective, and large weevil populations are encountered. Parasitism trends for the northwestern part of the San Joaquin Valley and the region adjacent to San Francisco Bay for 1939, 1940, and 1941 are shown graphically in figures 7 to 9; and for the agricultural area at Pleasanton, for 1939, in figure 12. The graphs were prepared in the same manner as reported by Michelbacher (1940*a*). The great reduction in population in the region adjacent to San Francisco Bay and Pleasanton as compared with the San Joaquin Valley is also clearly shown in table. 1.

To what extent secondary parasites will affect *Bathyplectes* still

remains to be determined. In 1940 seven individuals of a hyperparasite belonging to the genus *Eupteromalus* were reared from *Bathyplectes* cocoons collected in a field near Tracy. In alfalfa fields adjacent to San Francisco Bay, *Bathyplectes* cocoons were so scarce that a similar study could not be conducted. However, in the coastal regions we have an outstanding case of biological control, if the alfalfa weevil and *Bathyplectes* have come to equilibrium with the environment.

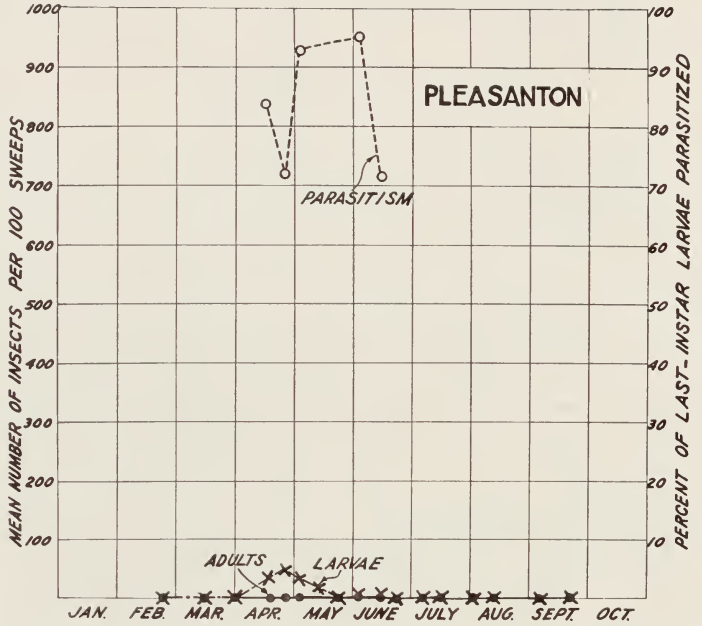

Fig. 12.—Alfalfa-weevil population and parasitism in the Pleasanton area, 1939; average number of larvae and adults collected per 100 sweeps of an insect net, and percentage of last-instar weevil larvae parasitized by *Bathyplectes curculionis*. In this area the alfalfa-weevil population reached such a low density that 1939 marked the last year that sufficient numbers could be collected for plotting.

A native dipterous larval parasite, *Madremyia saundersii* (Will.), was collected in 1934 in fair numbers in the region adjacent to San Francisco Bay. Although this is not an important parasite of the alfalfa weevil, the discovery is of interest, for it is the first record of this parasite's attacking the weevil in this country.

CHEMICAL CONTROL

In central California, insecticides have not been used in the control of the alfalfa weevil. Over most of the weevil's range it has never appeared in numbers sufficiently large to justify any treatment. In the Great Basin, effective insecticidal control has been developed, as reported by the following investigators: Reeves and associates (1916),

Reeves (1917, 1927), Newton (1922, 1923, 1933), Snow (1925), Doten (1927), Frederick (1930), Schweis (1928, 1931), and Sorenson (1932). There, dusting alfalfa with a mixture of equal amounts by weight of dusting sulfur and calcium arsenate at the rate of 4 to 5 pounds per acre has given excellent control. The dust is applied just as injury becomes noticeable, and at least 10 days should elapse between the time of application and the cutting of the first crop of alfalfa. Where recommendations are followed there is no danger of poisoning livestock.

SUMMARY

The extension of the region infested by the alfalfa weevil in lowland middle California since its discovery there in 1932 has not been great. At that time it was found in the following counties: Stanislaus, San Joaquin, Alameda, Santa Clara, and Contra Costa. South in the San Joaquin Valley the air-line extension has been hardly more than 6 miles. To the east the weevil has been found at a distance of about 25 miles from the known infestation in 1932. The southern boundary of the infestation cuts through an area of almost contiguous alfalfa fields; yet the pest has not extended its southern limit since 1933, when it was noted near Gustine, Merced County.

Because of the mild climate found in the lower elevations of central California, the weevil passes through at least two generations in a year. The portion of the year favorable to adult activity is longer in the more moderate climate prevailing near San Francisco Bay than in the more continental climate of the northwest portion of the San Joaquin Valley.

During the early years of the investigation the alfalfa weevil was most abundant in the region adjacent to San Francisco Bay. Since the introduction and establishment of the larval parasite *Bathyplectes curculionis*, the pest has been found most abundantly in the northwest portion of the San Joaquin Valley. The moderate climate found in the coastal region is better suited to the parasite than is the more continental climate of the San Joaquin Valley. In the former zone the parasite proved to be very effective in reducing the alfalfa-weevil population. In places the population has become so small that it is difficult to determine whether or not there has been any extension of infestation.

In the infested portion of the San Joaquin Valley the pest has done damage in a few fields, although over most of the area only very small populations are encountered. The most serious damage occurred in 1940, when a number of fields in a localized area suffered economic damage and several were almost completely defoliated. Damage was much reduced in 1941, and not a single field was seriously injured in 1942. Up to the present time the alfalfa weevil has not proved to be a serious pest, either in the San Joaquin Valley or in the cooler coastal regions.

Where an old field has a large weevil population and a new field is planted adjacent to it, there is danger of the recently planted field's becoming heavily infested during the first year. This gives evidence that the adult beetles may migrate in large numbers.

The pest can best be controlled by maintaining good stands of vigorously growing alfalfa, by timely cuttings, and by cutting the stubble as short as possible in the winter. Where stands are not so thick that they could be injured or where the danger of spreading disease is not too great, winter cultivation is desirable. Chemical control has not yet been attempted in central California, but in the Great Basin excellent control has been obtained by treating the alfalfa with a dust composed of equal amounts by weight of dusting sulfur and calcium arsenate. The dust, used at the rate of 4 to 5 pounds to the acre, is applied as injury becomes noticeable. The alfalfa should not be cut for at least 10 days after the application.

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